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REMARKS/ARGUMENTS

Amendments

Claims 16-20 have been canceled. This amendment has been made in the interests of speedy prosecution, and without prejudice to Applicant's right to prosecute such claims in a continuing application. For the record, it is also noted that Applicant intends to file one or more continuing applications to claim all aspects of the invention disclosed in this application but not claimed in claims 11-15.

The Rejection under 35 U.S.C. 103

Applicants respectfully traverse the rejection of claims 11-15 under 35 U.S.C. 103 as unpatentable over U.S. Patent No. 4,842,875 (hereinafter "Anderson") in view of U.S. Patent No. 5,045,331 (hereinafter "Antoon 331") and further in view of U.S. Patent No. 3,450,544 (hereinafter "Badran 544"), U.S. Patent No. 3,450,542 (hereinafter "Badran 542"), U.S. Patent No. 6,013,293 (hereinafter "De Moor"), and EP 752378 (hereinafter "Scolaro").

General

The amended claims of this application are directed to a particular aspect of the originally disclosed invention, namely the requirements for successfully ripening bananas inside a sealed polymeric bag. Claim 11 (the only independent claim) sets out a number of requirements, but for present purposes, the most important requirements are:

(1) bananas which have not yet reached their climacteric;

(2) a packaging atmosphere around the bananas which contains 14-19% oxygen; and

(3) a sealed container having an oxygen permeability/kg of bananas (OP13/kg) of at least 1500ml/am.24hr.

Bananas are fruits which ripen through a climacteric, meaning that the rate of respiration (and therefore consumption of oxygen and production of carbon dioxide) rises to a peak and then declines. Thus the bananas referred to in claim 11 can be bananas which are hard green and unripe, or bananas which have begun to ripen but have not yet reached the maximum rate of respiration which characterizes the ripening of bananas and other climacteric fruit. It is believed that the improved results provided by the present invention are attributable to a flattening of the peak of the typical respiration curve, as a result of the 16-19% oxygen content for at least part of the period before the bananas reach their climacteric, coupled with the high OP13/kg value of the sealed container.

The 14-19% oxygen content of the packaging atmosphere is entirely different from the much lower percentages recommended in the references relied on (for example 2-5 % in Anderson and Antoon 331, less than 7% in Badran 542, 4-10% in Badran 544, and 2-6% in Scolaro) and in the prior art generally (for example 2-5% in WO 92/02580 and Yahia), as discussed in detail below.

The OP13/kg requirement is related to the relatively high 14-19% oxygen content and to the oxygen demands of the ripening bananas, and provides a further distinction over the prior art, in particular Anderson, Antoon 331 and Scolaro, as discussed in detail below.

Detailed Comments on the References

A. There are at least the following differences between the primary reference, Anderson, and claim 11.

(1) Claim 11 requires that the packaging atmosphere contains 14 to 19% O_2. Anderson states (Table 1, column 3) that the optimum storage conditions for "banana, ripening" are an atmosphere containing 2-5 % O_2.

(2) Claim 11 requires that the sealed container have an O_2 permeability at 13°C per kg of bananas (OP13/kg) of at least 1500 ml/atm.24hr. Anderson requires that his membrane should "provide a flux of O_2 approximately equal to the predicted O_2 respiration rate" (column 2, lines 45-50). The O_2 respiration rate is identified in Table 1, column 3, as 44 cc of oxygen/kg.hr at 21°C, i.e. 1056 (44 x 24) ml of oxygen/kg.24hr at 21°C. This is far below the minimum O_2 permeability at 13°C per kg of bananas required by claim 11. Furthermore, the permeabilities of polymeric materials decrease with decreasing temperature. The O_2 respiration rate of Anderson's membranes at 13°C (i.e. the OP13/kg value specified in claim 11) will be substantially lower than 1056, i.e. even further below the minimum of 1500 required by claim 11.

B. There are at least the following differences between Antoon 331 and claim 11.

(1) Claim 11 requires that the packaging atmosphere contains 14 to 19% O_2. Antoon 331 states (Table 1, column 3) that the optimum storage conditions for "banana, ripening" are an atmosphere containing 2-5 % O_2.

(2) Claim 11 requires that the sealed container have an O_2 permeability at 13°C per kg of bananas (OP13/kg) of at least 1500 ml/atm.24hr. Antoon 331 requires that his panel should "provide a flux of O_2 approximately equal to the predicted O_2 respiration rate" (column 3, lines 33-43), and the O_2 respiration rate is identified in Table 1, column 3, as 44 cc of oxygen/kg.hr at 21°C, i.e. 1056 (44 x 24) ml of oxygen/kg.24hr at 21°C. This is far below the minimum O_2 permeability at 13°C per kg of bananas required by claim 11. Furthermore, the permeabilities of polymeric materials decrease with decreasing temperature. The O_2 respiration rate of Antoon 331's membranes at 13°C (i.e. the OP13/kg value specified in claim 11) will be substantially lower than 1056, i.e. even further below the minimum of 1500 required by claim 11.

C. There is at least the following difference between Badran 542 and claim 11.

(1) Claim 11 requires that the packaging atmosphere contains 14 to 19% O_2. Badran 542 states that the packaging atmosphere contains less than 7% O_2

(column 7, line 66), less than 5.5% O_2 (Claim 1), preferably 1-5.5% O_2 (claims 2 and 8, and column 3, lines 29-32), particularly 2-3% (column 7, line 70).

D. There is at least the following difference between Badran 544 and claim 11.

(1) Claim 11 requires that the packaging atmosphere contains 14 to 19% O_2. The O_2 contents disclosed in Badran 544 are below the 14-19% requirement of claim 11, namely 1.4-10%, more particularly 1.4-2.4%, for (ripe) bananas (claims 1 and 11).

E. There are at least the following differences between De Moor and claim 11.

(1) Claim 11 requires bananas which have not yet reached their climacteric. De Moor makes no reference to bananas.

(2) Insofar as De Moor is of any relevance to claim 11, which Applicant denies, the O_2 contents disclosed therein are below the 14-19% requirement of claim 11, namely 1-2% (column 1, line 49, for broccoli) and 5-8% (column 1, line 53, for cherries).

F. There are at least the following differences between Scolaro and claim 11.

(1) Claim 11 requires that the sealed container has an O_2 permeability at 13°C per kg of bananas in the container (OP13/kg) of at least 1500 ml/atm.24hr. In Scolaro's method, "unripe (green) fruit are kept, at room temperature and for a certain period of time, in bags with given characteristics of permeability to gas and aqueous vapor, filled with a modified atmosphere" (i.e. an atmosphere which is injected into the bag in place of the air, and whose constitution is different from that of air) -- column 1, line 53 - column 2, line 2. In the bag, "**the composition of the modified atmosphere remains substantially constant**" (column 3, lines 18-20, emphasis added). It is clear, therefore, that Scolaro's containers do not have an OP13/kg of at least 1500 ml/atm.24hr, since such permeability would result in substantial changes in the modified atmosphere. This is confirmed by the detailed disclosure of Scolaro's bags. Column 2, line 54 - column 3, line 2, of Scolaro describes a typical bag, which is made of a film of LDPE having an

oxygen permeability of 6800 cm^3/m^2.atm.24hr - the temperature at which the permeability was measured is not given, but in all likelihood was at or about 23°C, which is the normal temperature for such measurements. A bag made of such a film and of practical size would have an OP13/kg far less than 1500 ml/atm.24hr. For example, if the bag contained 1 kg of bananas, it would have to have an area substantially greater than 4.5 m^2 (6800/1500) in order to have an OP13/kg of at least 1500. Such a large bag would be wholly impractical.

(2) Claim 11 requires that the packaging atmosphere contains 14 to 19% O_2. Scolaro states that the modified atmosphere in his containers contains 2-20%, preferably 2-6%, of oxygen (column 2, lines 46-48). In the only specific example of Scolaro's invention, the modified atmosphere contains 2% of oxygen (column 3, lines 3-5). The ranges of oxygen content disclosed in the other references are consistent with Scolaro's preferred 2-6% range, but are completely at variance with Scolaro's broad 2-20% range. It is clear, therefore, that Scolaro's 2-20% range is a speculative proposal which requires undue experimentation in order to practice the invention over that broad range. Thus, there is no enabling disclosure in Scolaro for concentrations outside the range of 2-6%, and for the purposes of assessing the patentability of the present invention under 35 USC 103, the disclosure of a range of 2-20% should be ignored (MPEP 2121.01).

There is no suggestion or motivation in the references, either alone or together, to modify the references in a way which would lead to the invention claimed in claim 11. Indeed the reverse is true. For example, the references suggest an oxygen content far below the 14-19% range of claim 11 (2-5% in Anderson and Antoon 331; less than 7% in Badran 542; 1.4-10% in Badran 544; and 2-6% in Scolaro, insofar as it is enabled); and/or are not concerned with bananas at all (De Moor); and/or make use of containers whose oxygen permeability is far below that required by claim 11 (Anderson, Antoon 331 and Scolaro).

In connection with the failure of the references to disclose or suggest the 14-19% range of claim 11, reference may also be made to

(1) WO 92/02580, in which Figure 2 shows that the recommended atmosphere for bananas contains about 2-5% of oxygen; and

(2) Yahia E., 1997, Modified/controlled atmospheres for banana and plantains (Musa spp). Pages 104-109 in A.A.Kader (Anderson) California-97 Proceedings, volume 3; Fruits other than apples and pears. Postharvest Horticultural Series No. 17, University of California, Davis; in which page 104 states that bananas are very responsive to MA/CA when the fruit is at the pre-climacteric stage and that optimum atmospheres are different for different cultivars but are about 2 to 5% oxygen; and page 107 similarly states that the optimum atmosphere composition of bananas is 2 to 5% oxygen.

Copies of the relevant pages of these references are attached.

Comments on the Office Action

The Office Action asserts, without reference to any of the detailed disclosure of the references, that

> *The art taken as a whole, i.e. each of the references, also teaches that respiration, and thus the effect it has on gas levels, is a function of weight, temperature, type of produce, film permeability etc. and that these variables can be manipulated to provide optimal gas atmospheres for preservation and ripening.*

and that

> *... given this background of teachings throughout the art taken as a whole, to provide the gas permeabilities and thus gas atmospheres for a particular product such as bananas is considered to have been a routine determination fairly directed by the art taken as a whole.*

and that

> *... applicant is doing what the art taken as a whole fairly teaches.*

and that

> *The specific variables, if they do vary in their specific quantities, are a function of product and conditions selected.*

These assertions appear to be based on assumptions that

(1) "the art taken as a whole" extends beyond the disclosure of the references relied upon; and

(2) one of ordinary skill in the art would have ignored the differences identified above; would have carried out a comprehensive series of experiments, without regard to the oxygen levels recommended in the references relied upon, and in WO02/02580 and the Yahia reference; and would thus have identified the requirements set out in claim 11.

It is submitted that there is no basis for either of these assumptions, each of which is essential to the rejection, and that the rejection should, therefore, be withdrawn. As MPEP 2144.03 notes, quoting from Zurko, 59 USPQ 2d at 1697

> "The Board cannot simply reach conclusions based on its own understanding or experience – or on its assessment of what would be basic knowledge or common sense. Rather, the Board must point to some concrete evidence in the record in support of these findings".

The Examiner, who is of course under the same obligations as the Board, has not pointed to such concrete evidence

Applicant submits that, in view of the facts and arguments set out above, the Examiner has failed to establish a prima facie case for the rejection of claim 11 under 35 USC 103.

The Experimental Results

If, contrary to Applicant's submission, the Examiner maintains that a prima facie case has been made, Applicant will rely upon the experimental evidence in the specification to show that the claimed range of 14-19 % of oxygen achieves unexpected and valuable results relative to the prior art, thus rebutting the prima facie case and establishing the patentability of the invention (MPEP 2144.05 III)

Table 2 on page 23 of this application sets out the results of the experiments described in detail on page 22. In each of these experiments, 18.1 kg of green bananas were placed in a 38 x 50 inch bags of 2.2 mils thick polyethylene. In Example C34, the bags were left open. In Examples C31-33 and 3, the bags were sealed. The sealed bags included different atmosphere control members and, therefore, differed in the extent to which oxygen could enter the bag. The bags were maintained at 13°C for 36 days after packing, at which time half the sealed bags in each of Examples C31-33 and 3 were opened, and all the bags were placed in a commercial ripening room for about 24 hours (i.e. in an atmosphere containing ethylene at a concentration of 500 to 1000 ppm -- see page 14, lines 16-17). The bags of bananas were then stored until 49 days after packing, at which time the bags which were still sealed were opened, and the bananas inspected. As shown in Table 2, the oxygen content within the sealed bags 23 days after packing was 8.6% in Example C31, 9.8% in Example C32, 12.7% in Example C33, and 15.5% in Example 2; although not specifically so stated in Table 2, the oxygen content in the open bags of Example C34 was of course atmospheric, i.e. about 21%. The quality of the bananas, at the end of the tests, was excellent in the example of the invention (Example 3), in which the oxygen content was within the 14-19 % range of claim 11, but unsatisfactory in the comparative Examples, in which the oxygen content was lower (Examples C31-33) or higher (Example C34).

Continuation Application(s)

For the record, Applicant notes that it is his intention to file one or more continuing applications to claim the aspects of the invention disclosed in this application and not specifically claimed in claims 11-15. In this connection, attention is directed to the eleven aspects of the invention disclosed in the Summary of Invention on pages 4-9 of the application, and the associated disclosure in the Detailed Description of the Invention, including the specific Examples, on pages 10-32 of the application

CONCLUSION

It is believed that this application is now in condition for allowance, and Applicant respectfully requests that a timely Notice of Allowance be issued in this case. If, however, there are any outstanding issues that could usefully be discussed by telephone, the Examiner is asked to call the undersigned.

Respectfully submitted

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PCT

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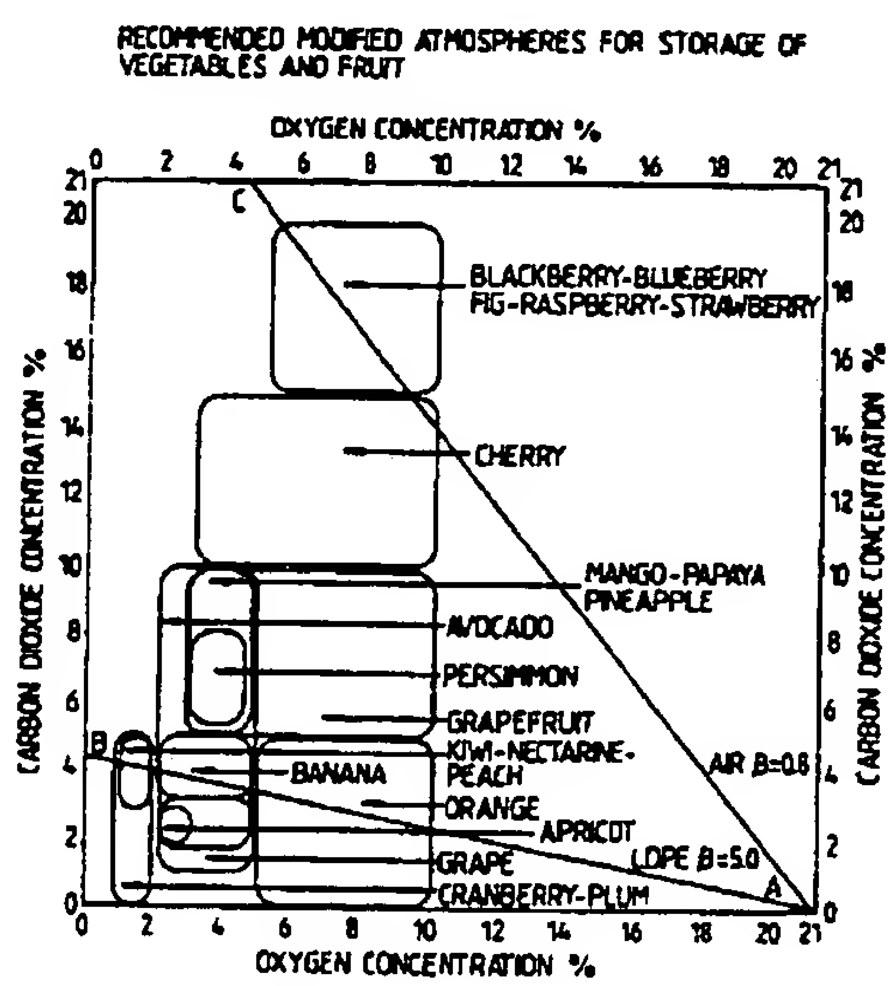
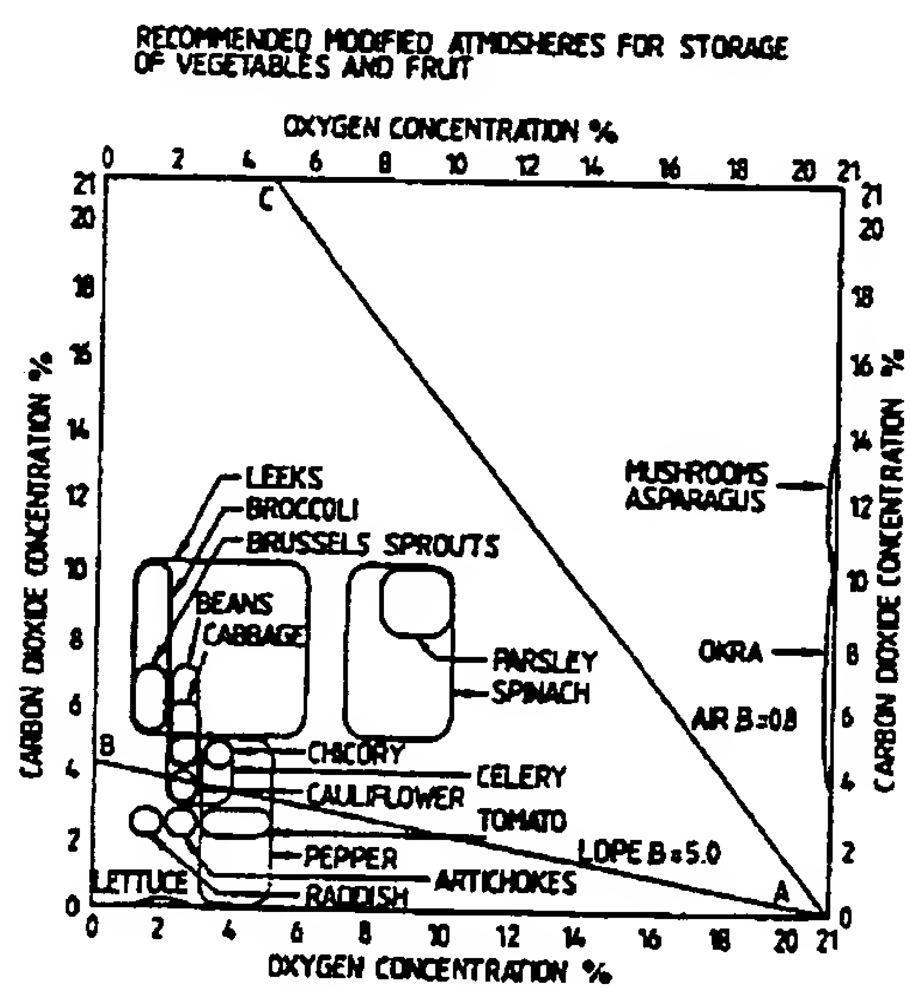
(54) Title: CONTROLLED PERMEABILITY FILM





(57) Abstract

A controlled permeability film including a film forming polymer and optionally including a dispersing polymer; and an inert porous filler optionally having a surface modifying agent coated thereon, the inert porous filler being present in an amount effective to reduce the ratio of the carbon dioxide permeability to the oxygen permeability of the film, and wherein the filler has a particle size greater than the intrinsic film thickness of the film forming polymer. A composite packaging article and a packaged produce product are also disclosed.

In a preferred aspect of the present invention the controlled permeability film may be utilised in the packaging of product including highly sensitive produce such as broccoli.

Accordingly in a preferred form there is provided a packaged produce product including;

a controlled permeability film including

a film forming polymer optionally including a dispersing polymer; and

a porous filler wherein the filler has a particle size greater than the intrinsic film thickness of the film forming polymer, optionally having a surface modifying agent coated thereon, in an amount effective to reduce the ratio of the carbon dioxide permeability to the oxygen permeability of the film; and

a produce product packaged therein.

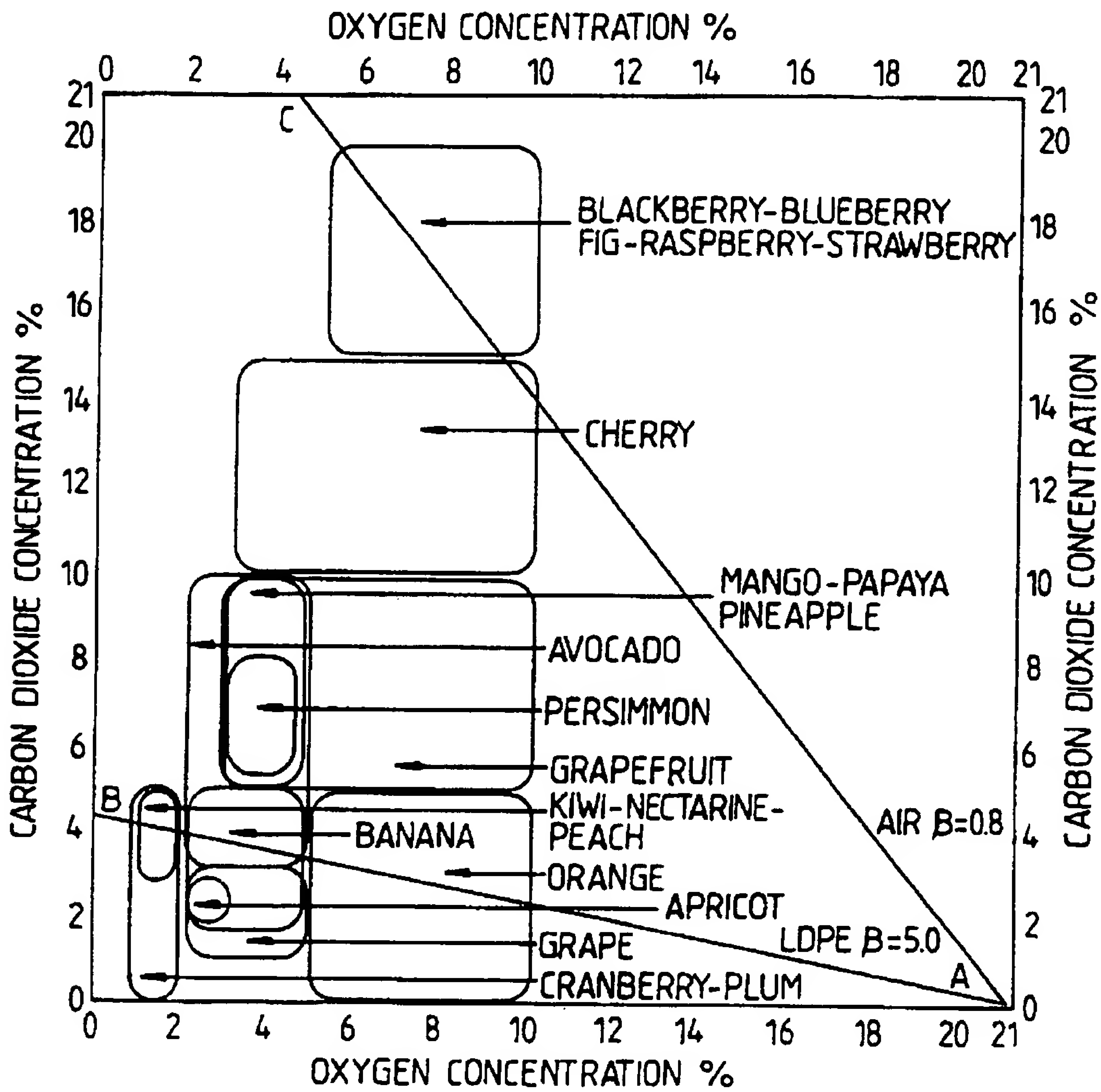
The controlled permeability film may be utilised in the packaging of highly sensitive produce such as broccoli and the like.

The produce packaged may be of any suitable type sensitive to oxygen deterioration. The produce may be selected from Broccoli, Brussels Sprouts, Beans, Cabbage, Chicory, Celery, Cauliflower, Radish, Artichoke, Lettuce, Tomato, Pepper, Leeks, Parsley, Spinach, Asparagus, Mushroom and Okra, flowers, berries, cherry, melons, mango, papaya, pineapple, avocado, persimmon, grapefruit, kiwi, nectarine, peach, apple, banana, orange, apricot, grape, cranberry, plum, pear and nashi (see Figure 2).

The packaged produce product has been found to exhibit improved CO_2/oxygen permeability such that the deterioration of the produce product is significantly reduced. It will be recognised that the atmospheric oxygen and CO_2 concentrations may be optimised to be within the optimum ranges for a produce product. Figure 2 illustrates the preferred optimum windows of Carbon Dioxide concentration to Oxygen concentration for various produce items. Reported optimum O_2 and CO_2 concentrations for broccoli range from approximately 1 to

Fig. 2.

RECOMMENDED MODIFIED ATMOSPHERES FOR STORAGE OF VEGETABLES AND FRUIT



Modified/Controlled Atmospheres for Bananas and Plantains (*Musa* spp)

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MA/CA extends the storage life of green bananas (Mapson and Robinson 1966; Scott and Robert 1966; Smock 1967; Barden and Lima 1969; Woodruff 1969b; Liu 1970; Quazi and Freebairn 1970; Scott et al. 1970; Fuchs and Temkin-Forodeiski 1971; Scott 1971; Duan et al. 1973; Scott and Gandanegara 1974; Burg 1975; Scott 1975; Liu 1976a; Liu 1976b; Scott and Chaplin 1978; Brown 1981; Satyan et al. 1992a; Satyan et al. 1992b; Banks 1984a; Hesselman and Freebairn 1986; Kanellis et al. 1989a; Yahia, 1997; Yahia and Paull, 1997). Bananas are very responsive to MA/CA when the fruit is at the preclimacteric stage (Smock 1979). Optimum atmospheres differ for different cultivars but are about 2 to 5% O_2 and 2 to 5% CO_2, and optimum temperature for MA/CA storage is 13°C (Woodruff 1969b). Cooking bananas have similar CA requirements (Satyan et al. 1992b). Atmospheres containing 5% O_2 and 5% CO_2 were found to be suitable for 'Gros Michel' bananas held for 20 days at 12C (Wardlaw 1940). 'Lacatan' and 'Dwarf Cavendish' bananas were kept for 3 weeks in atmospheres containing 6 to 8% CO_2 and 2% O_2 at 15°C (Smock 1967). The recommended atmosphere for 2 Malaysian cultivars of bananas at 20°C and 80% RH was 5 to 10% CO_2 and a continuous removal of ethylene (Broughton and Wu 1979). Atmosphere of 1% O_2 inhibited ripening in green bananas and was considered as the lower limit at 15.5°C (Parsons et al. 1964). O_2 concentrations less than 1% cause fruit injury which include dull yellow to brown skin discoloration, failure to ripen, flaky gray flesh, and off-flavors (Parsons et al. 1964). However, 1% O_2 was reported by other researchers (Mapson and Robinson 1966; Chiang 1970) to result in poor quality and more stalk rot. Furthermore, research by Hesselman and Freebairn (1986) have indicated that O_2 levels less than 2.5% affect the taste of 'Valery' bananas. CO_2 concentration higher than 5% are reported to result in undesirable flavor and texture after fruit ripening (Woodruff 1969b). CO_2 level of 10% was considered to be the upper limit for 'Gros Michel' bananas (Gane 1936).

Experiments were conducted with storage of bananas in CA sealed rooms (Woodruff 1969b). Rooms were flushed with N_2 to reduce the O_2 level and supplemental CO_2 was added. Water scrubber was used to control the CO_2 concentration. Purifiers containing brominated, activated carbon were used to absorb volatiles (including ethylene). CA markedly reduced the crown rot. Woodruff (1969b) listed 4 advantages of CA storage of bananas including 1) fruit can be held for long periods without significant ripening or turning. 2) decreases incidence of rots and molds. 3) maintains a fresher appearance fruit, and 4) more flexibility in coping with glutted markets. However, there has been no commercial CA storage for bananas. Bananas are available all year around, and therefore there is no need for long-term storage. Gas tight CA chambers would have to be built aboard ships, since most of the postharvest life of bananas is maintained during transit. In the past this was not technologically feasible, however, the recent advances in CA technology and

marine containers facilitates the application of CA aboard marine ships, which can provide a postharvest life of up to 2 months.

MA has been used commercially for the last 3 decades during marine shipments of banana (Woodruff 1969a; b). In this system green fruits are usually packed in polyethylene bags of about 0.04 mm (1.5 mil) thickness, which are then evacuated (usually using a vacuum cleaner) and sealed (Woodruff 1969a). High temperatures at the time of evacuation accelerate the establishment of the desirable atmosphere (Woodruff 1969b). The atmosphere in these bags usually averages about 2.5% O_2 (1 to 4.5%) and 5.2% CO_2 (4 to 6%) after 3 to 4 weeks. This system has been called "Banavac" by United Fruit Company (Smock 1979; Woodruff 1969b). Bananas can be held for 30 days by this method, and can be maintained green for up to 60 days but rots increase and quality declines after 30 days (Woodruff 1969b). Fermentation problems have occurred in up to 1% of fruits shipped in this system (Woodruff 1969a). Only green fruits should be used, and care should be taken not to use punctured bags. Punctured bags will not allow the development of an appropriate atmosphere. Ripe fruits would increase the accumulation of ethylene inside the bags, and would further stimulates fruit ripening. Ethylene concentration of 10 ppm accelerated the ripening of 'Valery' bananas (Woodruff 1969b). A concentration of 10 ppm or more of ethylene can also stimulate the softening of green fruit (Chiang 1968; Chiang 1970), a condition known as "soft-green" (Woodruff 1969b) or "green ripeness" (Scott 1975). High temperature, high CO_2, and low O_2 in the storage atmosphere were suggested to be the main factors causing this disorder, however, the exact mechanism is not fully understood (Zhang et al. 1993). The use of ethylene absorbent agents such as potassium permanganate absorbed on aluminum silicate or vermiculite inside the bags can prevent this disorder and prolong the postharvest life of the fruit (Scott et al. 1968; Liu 1970; Scott 1975). Ethylene removal with brominated carbon was found to extend the storage life of 'Lacatan' and 'Cavendish' bananas held in 2-3% O_2 and 8% CO_2 (Smock 1967), and was found to be more effective than using molecular sieve 5A in a continuous air and C_2H_4 stream (Chiang 1968). The use of MA for bananas was found to prolong their storage life even at ambient temperatures (Scott and Gandanegara 1974).

The use of sealed polyethylene (0.1 mm thickness) containing 100 g vermiculite impregnated with a saturated solution of $KMnO_4$ allowed a storage life of 'Williams' bananas for up to 6 weeks at 20 to 28°C and 16 weeks at 13°C (Satyan et al. 1992a; b). 'Latundan' banana was stored in 0.08 mm thick polyethylene bags for up to 13 days at 25-30°C (Agillon et al. 1987). Storage of green mature 'Cavendish' bananas in low density polyethylene bags (0.05 mm thickness) for up to 30 days at 8, 11 and 14°C developed an in-package atmosphere of 3 to 11% O_2 and 3 to 5% CO_2 (Hewage et al. 1995). However, these authors reported that these storage conditions did not affect ripening and sensory quality, nor did they alleviate CI symptoms developed at 8 and 11°C. 'Emas' bananas stored in polyethylene bags (0.04 mm thickness) for 6 days at 24°C generated an atmosphere of up to 3% C_2H_4, up to 14.6% CO_2, and as low as 2.9% O_2 (Tan et al. 1986). Accumulation of 10% CO_2 or more, especially from day 3 to day 6, and an O_2 concentration below 2% in the bags caused abnormal ripening when fruit was ripened later in air. Fruit had skin and pulp darkening, and softening of the inner portion of the pulp, eventhough the outer portion remained hard. Water insoluble protopectins decreased, and water soluble pectins and pectates increased in wrapped fruits. The authors suggested that a minimum of 10% CO_2 for few days is required to cause injury in 'Emas' bananas. CO_2 (10%) injury was also reported for 'Mas' bananas (Abdullah et al. 1987). Several cultivars of cooking banana ('Bluggoe', 'Pacific plantain', 'Blue Lubin', and 'Pisang Awak') behaved similarly to the dessert cultivar 'Cavendish' when stored in

polyethylene bags (0.1 mm) with or without an ethylene absorbent (potassium permanganate on aluminum oxide) at 7, 13, 20, and 28°C (Satyan at al. 1992b). The storage life increased by a factor of two in the absence of an ethylene absorbent and a factor of three in the presence of the ethylene absorbent. CO_2 concentration inside the packages increased up to 15%, and concentrations as high as 32% were reported at the end of storage. Packaging with or without ethylene absorbent had no effect on the incidence of chilling injury (CI) neither in the cooking banana cultivars nor in 'Cavendish'. The authors suggested that this method of sealing in polyethylene bags "appears to be an alternative method to refrigeration" (!).

Liu (1976a) suggested pretreatment of the fruit with ethylene at the production or packing site before storage or shipping, to avoid post shipping treatment due to high costs, and to provide even ripening. 'Dwarf Cavendish' pretreated with ethylene and stored for 28 days in 1% O_2 or in 0.1 atmospheric pressure at 14°C remained green and firm until the end of the storage period, and started to ripen almost immediately after being placed in air at 21C without additional ethylene treatment. However, the period of ethylene pretreatment is critical and should not exceed a "threshold length of time (TLT)". The TLT is defined by Liu (1976b) as the minimum time required for a fixed concentration of ethylene treatment to induce banana ripening response. Only bananas which had been pretreated with ethylene for a period equal to TLT were successfully stored in CA (Liu 1976a). Neither CA nor LP could prevent the ripening of bananas pretreated with ethylene for a period longer than TLT. Fruits are not uniform in their TLT. Commercially mature bananas may have TLT between 4 and 20 hours, and a test for TLT requires 1 to 2 days (Liu 1976b). Therefore, from a practical point of view the author concluded that it would be extremely difficult to select large lots of fruit with uniform TLT, and thus the potential hazard of fruit ripening during storage or shipping after excessive ethylene pretreatment jeopardize the commercial applicability of this method.

Treatment with "Prolong" (a mixture of sucrose esters of fatty acids and sodium salt of carboxymethylcellulose) extended the shelf-life of bananas (Lowings and Cuts 1982; Banks, 1984a; 1984b). The commercial wax "Decco Luster 202" at a 1:2 (wax:water, v/v) delayed ripening of 'Saba' bananas (Pastor and Pantastico 1984), but other formulations ("Carbowax" and "Prima Fresh") had no effect. The action of "Pro-long" has been attributed to increased resistance to CO_2 diffusion and to O_2 creating an internal atmosphere with a reduced O_2 and elevated CO_2 (Lizada and Novenario 1983).

'Gros Michel' bananas held in a low pressure (LP) of 150 mm Hg at 15°C were maintained longer in a better quality than those held in normal pressure (Burg and Burg 1966). Fruits held in LP of 760, 250, and 80 mm Hg at 14°C were reported to be maintained for 30, 60, and at least 120 days, respectively. The authors reported that fruits had an acceptable texture, taste, and aroma, and no injury.

The quality of green bananas was not affected when fruits were held for up to 7 days in 100% N_2 at 15.5°C, but had dark-brown to black skin blemishes when held for 10 days (Parsons et al. 1964). After 4 days in 100% N_2 at 15.5°C, fruits ripened to a normal color and flavor in 13 days at 20C. However, fruit failed to ripen in air, and developed decay, brown skin discoloration, and off-flavor after storage in 100% N_2 for 7 days. Fruits were ripened normally in air at 20°C after being held in 99% N_2 and 1% O_2 at 15.5°C for 10 days.

Low O_2 (2.5%) suppressed the activity of acid phosphatase, and the addition of 500 ml of ethylene to the low O_2 atmosphere did not reverse this suppression (Kanellis and Solomos 1985; Kanellis et al. 1989a). However this atmosphere either alone or in combination with 500 ml

ethylene prevented the decline in the activity of pectin methyl esterase. Kanellis et al. (1989a) suggested that there was differential effects of low O_2 on metabolic processes since that the accumulation of sugars increased gradually for 4 days in low O_2, but no increase in acid phosphatase was observed throughout the duration of the low O_2 treatment. Low O_2 (3%) limited the operation of the Krebs cycle in fruits of Musa paradisiaca L., but high CO_2 showed no rate limiting steps in this cycle (McGlasson and Wills 1972). Ali Azizan (1988) reported that high CO_2 suppressed the activities of ADH, LDH, PDC, and phosphofructokinase (PFK), but not malic enzyme and phosphoenol pyruvate carboxylase in 'Pisang Mas' bananas.

Optimum atmosphere composition for bananas is 2 to 5% O_2 and 2 to 5% CO_2. These atmospheres delay fruit ripening without causing any deleterious effects. CA can maintain the fruit for a longer period in good quality. Although a recent a report (Blankenship 1996) indicated that bananas that have ripened under CA conditions are not as high quality as those ripened in air in terms of visual appearance. MA, sometimes in combination with ethylene-absorbent agents, are commonly used during long-distance marine transport. LP also can maintain the fruit for a longer period in a very acceptable quality. However, due to availability of the fruit almost all year around and because of costs considerations, CA is not commonly used and LP is not commercially used. There is potential for the use of CA on marine ships. Research needs for this fruit include investigation on the cost and technological feasibility of the establishment and use of CA (Yahia, 1997; Yahia and Paull, 1997).

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